Application of weighted graphs in evaluating effectiveness of a build routing in the video game "Eternal Return : Black Survival"

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***Abstract*—This study attempts to use graph theory to evaluate the effectiveness of build routes in the video game Eternal Return : Black Survival, The result shows that graph theory can provide a rough estimate of how effective a build is, yet still lacks in analyzing in depth and more advanced concepts vital in a higher rank environment**

***Keywords*—Build routing, Discrete Mathematics, Effectiveness, Weighted graph.**

I. INTRODUCTION

"*Eternal Return: Black Survival"* is a free to play Anime MOBA Battle-Royale video game where a team of three players each play as a unique "Test Subject" and are tasked to survive in "Lumia Island" against 7 other teams in a fight for survival until there is only one team remaining.

Eternal Return : Black survival (which from this point forward will be referred to as ER:BS) has a unique twist that makes it different from other MOBA type video games, in which instead of purchasing base items to purchase and craft items of higher grades, players instead have to loot and find base materials in the island in order to craft their gear.

To ensure that the game does not last for extended periods of time, ER:BS implements a "Day and Night" system. The game would start at Day 1, then after a few minutes it turns into Night 1, Day 2, and so on until Day 6 where there will be no more arenas remaining. When an area is closed, a timer will start ticking down until 0, which at that point would cause the player to explode and immediately die. The only way to recharge this timer is by killing other players.

The important part of this system is that during specific points, "rare" materials which unlocks legendary and more powerful gear, become available and have limited amounts, which means players must race or even fight in order to obtain these rare items. With this system, it is crucial that the player finishes their build before Day 2 begins (first rare material drop of 2 "Life Trees" and "Meteors" all spread and on specific locations) so that they can prepare by farming for levels and/or scouting the area beforehand.

Fig 1.2 Impact of an effective build, allowing players to be more aggressive and win fights earlier. Screenshot taken from a recording on 6/11/2023

II. LITERATURE REVIEW

A. Graphs

In discrete mathematics, a graph is a representation of discrete objects and the relation between them. A graph G is defined as the following

$$G = (V,E)$$

Where,

V = a non-empty set of vertices (or objects)
$= \{v_1, v_2, \dots, v_n\}$

E = a set of edges that connects two vertices together
$= \{e_1, e_2, \dots, e_n\}$

Graphs are then categorized based on the properties that the vertices have

1. Based on the existence of loops or multiple edges with the same vertices:
    1. Simple graph:
    graphs that do not contain multiple edges or loops

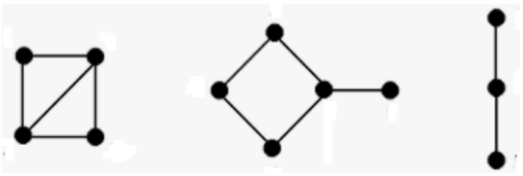

Fig. 2.1 example of simple graphs, source: https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2023-2024/19-Graf-Bagian1-2023.pdf accessed at 11/12/2023

2. Non-simple graph:
   Non-simple graphs are split into more categories
   a. Multigraph :
      Graphs that have multiple edges
   b. Pseudograph
      Graphs that have loops

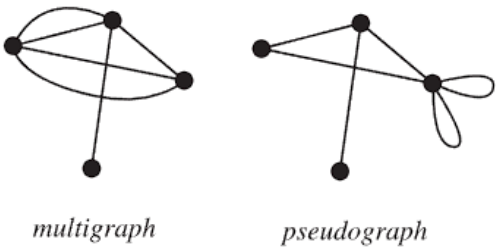

Fig. 2.2 example of non-simple graphs, source: https://mathworld.wolfram.com/Graph.html accessed at 11/12/2023

2. Based on the orientation of edges:
   1. Undirected graphs:
      graphs where edges do not have a direction

   2. Directed graph:
      graphs which edges have a direction.

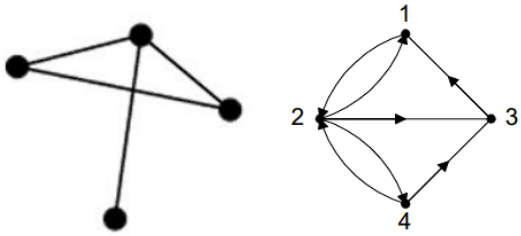

Fig 2.3 left – undirected graph
Right – directed graph
Both taken from
https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2023-2024/19-Graf-Bagian1-2023.pdf accessed at 11/12/2023

There are a few terminologies relevant in this study:

- Adjacency
  Two vertices are considered adjacent to each other if they are directly connected
- Paths
  A path is an order of vertices from V0 that forms a connected path to another vertices

B. Connected graphs

Two vertices in a graph are considered connected if there exists a path between the two. Then, if all of the vertices in a graph are connected, then that graph is a connected graph

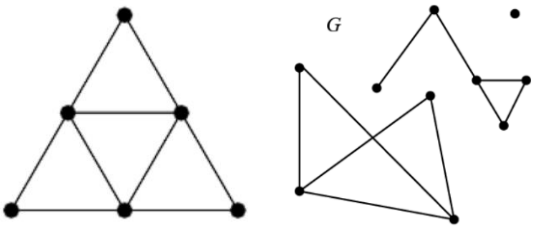

Fig 2.4 a connected graph (left) and an un-connected graph (right), source : https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2023-2024/19-Graf-Bagian1-2023.pdf accessed at 11/12/2023

In a directed graph, the connection between two vertices can be further categorized to either strongly connected or weakly connected.

Strongly connected vertices mean that if there exists two vertices u and v, then there is exists a path from u to v and from v to u

Weakly connected vertices are two vertices u and v where there exists a path from u to v, but not from v to u.

With this, in terms of connectivity there are two types of connected directional graphs:

- **Strongly connected graph**: All of the vertices are strongly connected (no weakly connected vertice)
- **Weakly connected graph:** There exists a pair of weakly connected vertices

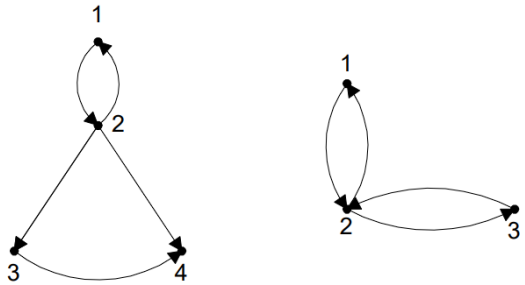

Fig 2.6 An example of a weakly connected graph (left) and a strongly connected graph (right), source: https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2023-2024/19-Graf-Bagian1-2023.pdf accessed at 11/12/2023

C. Weighted Graph

A weighted graph is a graph where every vertices has a numerical value (or weight). Weighted graphs can be used to calculate the price or value of a certain path in a graph

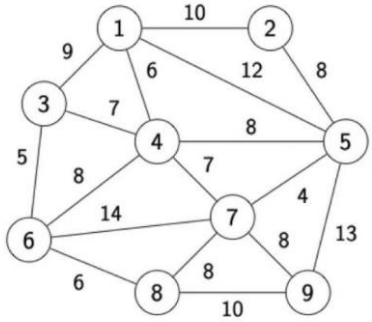

Fig 2.5 a weighted graph, source : https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2023-2024/22-Pohon-Bag1-2023.pdf accessed at 11/12/2023

C. Sub-graphs

Sub-graphs are graphs that partially has the vertices and edges of a graph, so that if there exists a graph G = (*V*,*E*), there is a sub-graph $G_1 = (V_1,E_1)$ where $V_1 \subseteq V$ and $E_1 \subseteq E$.

A path can be considered a sub-graph as it is part of a graph that shows the connection between two vertices

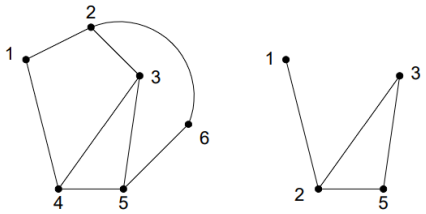

Fig 2.6 A graph (left) and a subgraph of the graph (right), source : https://informatika.stei.itb.ac.id/~rinaldi.munir/Matdis/2023-2024/19-Graf-Bagian1-2023.pdf accessed at 11/12/2023

III. METHOD

A build routing is basically a path inside Lumia Island that is used to help the player stay organized, especially for newer players when they're not used to the whole looting loop yet

The bare minimum for a routing to be acceptable is that it contains all of the items, or leave one remaining which can either be obtained somewhere or immediately purchased via drone

A. Defining a good routing

A good routing allows the player to quickly finish their build so that they can focus on:

- Takes at most 4 areas for the build to be complete
- Ends in a POI (Teleporter or Bear)
- Ensures that the player has enough inventory space

In this study, point one (area count) and two (POI) will be considered when adding weigh to paths between area

Two areas are considered adjacent if a player can immediately access the target area from the starting area without entering another area (From A to B without intermediary areas), there are currently two methods of traversing in ER:BS :

a. By walking
b. By using a *hyperloop* (marked on the map as the blue >> icon).

B. Lumia Island as a graph

1. Basic Map Layout

Lumia Island has 19 Main areas which contain useful materials for players to loot and animals that drop items and give experience, as well as 2 Special Areas.

- "Research Center" which is always closed, has no items, and is the place where "Wickeline" spawns, a boss that drops "VF Blood Sample" which is considered the rarest and strongest item in the game.
- Abandoned Dock (marked in the map as "???"), a place where a team can escape with a submarine.

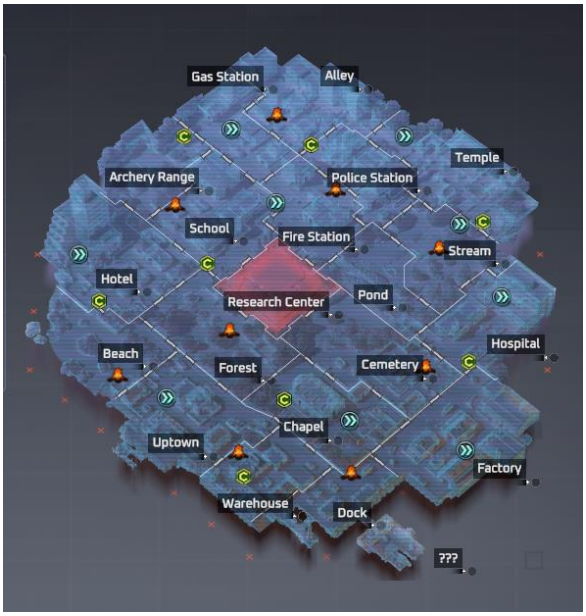

Fig. 3.1 Lumia Island preview in the "Item catalog" menu, screenshot taken on 10/12/2023

Two areas are considered adjacent if there is a valid path between both areas (Marked with a slightly thicker white rectangle on the map). For the sake of simplicity, multiple paths between two areas will only count as 1 (e.g. Chapel and Cemetery has 3 gates but will only be considered as a single vertex), adjacent areas are also considered strongly connected.

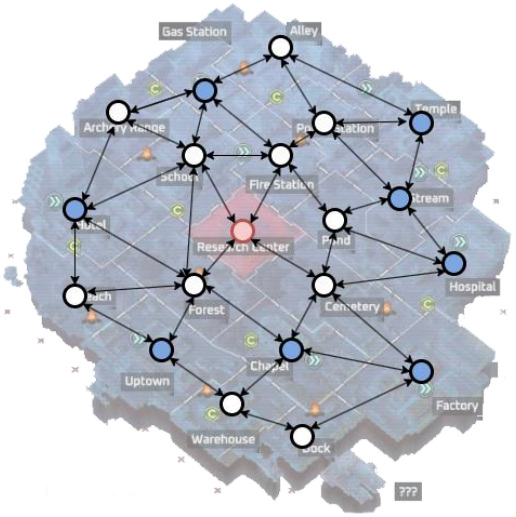

Fig 3.2 Directional graph of Lumia Island's areas (by walking)

2. *Hyperloops*

Hyperloops are essentially teleporters that allow a player to immediately be transported to any area, including the area where the player currently is. Because of the nature of *hyperloops*, an area with one is considered to be adjacent to all other areas, but not the other way around. This means that an area with hyperloops is considered to be weakly connected to all areas

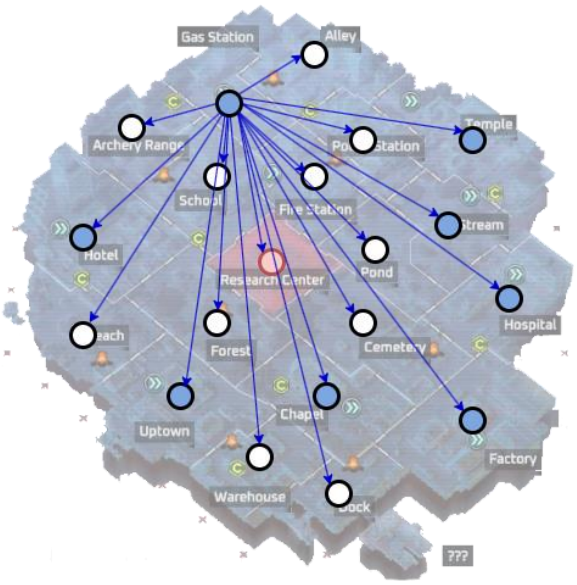

Fig 3.3 Directional sub-graph depicting the adjacency of "gas station" with all other areas due to hyperloops.

3. Start of a game.

Before the game starts, players can choose an area to first spawn in, which means in the graph we will start in an imaginary area that is adjacent to ALL areas (except the special areas)

When considering paths, we will assume that the player always takes the shortest route, and prefers using the hyperloops over walking. In an actual game, a player may instead choose to walk in-order to farm wild animals along the way, or pass through an area with an item that the player couldn't obtain due to high traffic of other players

C. Factors for graph weight

In this study, the concept of weighted graphs will be used to score building routes, which are a path from the main graph of Lumia Island, by adding weights between two areas according to the points mentioned earlier in point A.

The higher the weight means that the particular move is optimal and effective, the smaller the weight, the less effective it is.

Therefore, the weights for an edge from A to B will have the following weights.

- Basis of –6 when entering an area and for every area between it to discourage using more than 4 areas (except for the starting area)
    - example 1 : traveling from beach to archery range will cost -12 because the player needs to go to hotel and then archery range
    - example 2 : traveling from uptown to temple will only cost -6 because the player can teleport, otherwise by foot it would cost -30
- A +2 for every required item obtained in the following area
    - Example 1 : going from uptown to beach and picking up 3 items gives us 6 points.
    - Example 2 : if we wanted to grab an item at archery range from beach, when walking through hotel it gains us 0 points because we do not take anything from it

(both of the following examples only account for items and not travel cost)

- If the following area is the last area in the build route and it ends in an area that has a POI, the weigh gets + 6

  List of POIs
    - Areas with wild animals as POI : Gas Station, Alley, Temple, Stream, Dock, Warehouse, Uptown, Beach, Archery Range
    - Areas with tree of life at Day 2: Cemetery, Temple
    - Meteors have random drop location and will not be accounted for simplicity

IV. RESULTS

As a demonstration, I will be using the above method to calculate two build routings, a good routing (publicly available, has high rating, and relatively high win rate) and a bad routing (An example of an inefficient route that I made) :

1. Good route example

(a)

(b)

Fig 3.4 (a) Routing preview (b) list of items needed in each area

1. Starting at forest, we obtain a grand total of 11 items, giving us 22
2. We then travel to Uptown, costing -6 points but in uptown we get 5 items, resulting in a total of 26 Points
3. Finally, we go to dock for -6 points and grab 5 more items, with the pre-final total of 30 Points
4. Because we end in the docks and it has a POI (bears), we get an extra 6 points for a total of 36 points

2. Bad route example

(a)

(b)

Fig 3.5 (a) Routing Preview, (b) list of items needed in each area

1. Starting at hotel we obtain 9 items for a total of 18 points (NOTE : Leather, Sticks, and Stones are generally available in all parts of the map, but we assume it is obtained in the first area for simplicity)
2. We then travel to school for -6 points, and grab 5 items for a total of 22 points
3. Teleporting from school to cemetery costs us another -6 points, we grab 4 items so we end up with 24 points
4. Walking to pond for -6 points and grabbing 4 items for a total of 26 points
5. Finally walking to fire station for -6 points and grabbing only 2 items causes us to lose 2 points, ending with 24.

With the above method, we can see that a good route which takes 3 areas, has effective routing, and ends in a POI result in 36 points, tentative depending on the chosen items. And with the bad example getting 24 points in a best-case scenario.

Note that this doesn't account for delays such as item scarcity that may happen if a lot of players happened to start at that particular area

V. CONCLUSION

While the above method can give a rough estimate for how effective the routing of a build is, there still exists a lot more factors that can affect real gameplay, such as when and which area is a specific item (e.g. Main Weapon) is finished, as it allows the player to fend their selves against other players that might be faster. Other factors such as wild animal spawn time range could also be counted into consideration as it would also give the player a boost.

VI. GLOSSARY

Farming – Esp. in Video games, to do a task in game that leads to obtaining levels or a specific item

Looting – Searching for a set of items, usually from itemm

containers or on the ground in an area

MOBA – Multi player online battle arena, a genre of video games where players control a character with unique skills and abilities, and fight against each other in an arena

Purchasing via drone – Immediately obtain a white rarity (lowest rarity) item by spending credits (a resource that can be gained overtime, eliminating players and wild animals in game).

VII. ACKNOWLEDGEMENT

I would like to thank the Indonesian ER:BS "Lyfin's Tavern" for sharing their experiences and opinions on regarding route effectiveness also a good friend of mine "Rev", for always paying ER:BS together with me.

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STATEMENT

I hereby declare that the paper I wrote is my writing, and is not an edit, a translation of an existing paper, nor a form of plagiarism

Bandung, 3 Desember 2023

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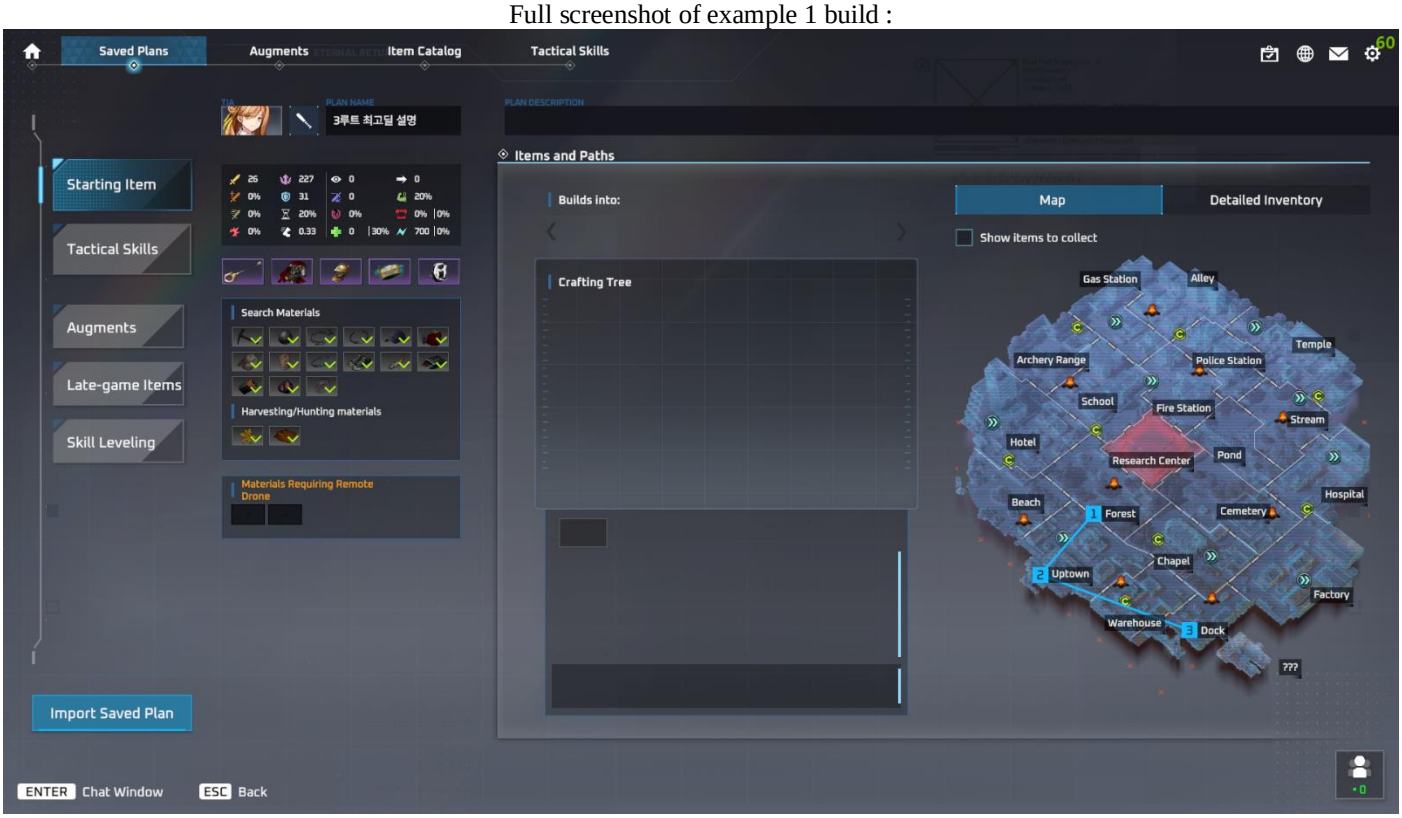
Full screenshot of example 1 build :



Full screenshot of example 2 build :